Activity D.1.3.
Development of a list of requirements and basic principle drawings for a simple and efficient integrated climate control system

Développement d'une liste de pré-requis et de principes de base pour une centrale intégrée de traitement d'air simple et efficace

GOURLOT J.-P.

Arusha, January 2012

From a joint work by:
A partir d'un travail conjoint de :
Payet and Gourlot

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Plan of presentation

Cotton Testing in Africa
CSITC - Project

1 - Introduction

2 - Description of the technical objective

3 - Ambient Air Management System Requirements

4 - Method for controlling the AMS equipment

5 - Conclusion

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Plan of presentation

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1- Introduction

- From expertise tours in laboratories: basic standards required for cotton testing sometimes not completely respected
- System very complex
- Manufacturer could miss some technical information about how to regulate both temperature (T) and relative humidity (RH) of the air in approved tolerances
- Provide to laboratories a full description of the system

- Selon les expertises réalisées en laboratoires : certains critères de base nécessaires au test du coton ne sont pas toujours respectés
- Système très complexe
- Le fournisseur peut omettre certaines informations techniques concernant la régulation simultanée de la température (T) et de l'humidité relative (HR) de l'air dans les tolérances normales
- Fournir aux laboratoires un descriptif détaillé du système

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Plan of presentation

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2- Description of the technical objective

- Recognition of the classing laboratories using SITC at the international level in terms of air management
- List of technical requirements and recommendations:
  - standards dealing with textiles testing
  - additional experiments to check that every requirement is effectively fulfilled for installing, improving or controlling the equipment
- With this knowledge, laboratories should be able to prove their capacity for maintaining their climate control system within the worldwide agreed tolerances

- Reconnaissance internationale en termes de gestion de l'air des laboratoires de classement utilisant des CMI
- Liste des critères techniques et recommandations :
  - normes relatives aux essais sur textiles
  - expériences complémentaires de vérification lors de l'installation, l'amélioration ou le contrôle des équipements
- Avec ces connaissances, les laboratoires seront en mesure de prouver leur capacité à maintenir leurs conditions dans les tolérances exigées au niveau mondial

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Plan of presentation

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3.1- Reasons for working in standard conditions

- Cotton is hygroscopic
- Moisture content (MC) depends on Relative Humidity (RH)
- *RH change 8-10% → MC change 1%*
- Influence on cotton properties (maturity, length, strength)
- *RH change 3-5% → Strength change 1 cN/tex (Sasser, 1990)*

- Propriété hygroscopique du coton
- Le taux de reprise (TRL) dépend de l'Humidité Relative (HR)
- *HR change 8-10% → TRL change*
- Influence sur certaines propriétés du coton (maturité, longueur, ténacité)
- *HR change 3-5% → ténacité change 1 cN/tex (Sasser, 1990)*

Moisture %	Length mm	Strength grams/ tex
6.5%	24.02	22.53
7.5%	24.49	24.50
8.5%	24.95	26.87
9.5%	25.42	28.44

Moisture %	Length mm	Strength grams/tex
6.5%	32.42	34.76
7.5%	33.05	37.80
8.5%	33.67	40.84
9.5%	34.30	43.88

USTER, Influence of moisture content on UHML and Str of Short-Weak (left) and Long-Strong (right) cottons

→ Bring cotton to EMC so that UHML and Str variations and levels can be comparable intra- and inter-laboratories

→ Amener le coton à l'équilibre hygroscopique pour éviter les variations d'écart/de niveau (UHML, Str) en intra- et inter-laboratoire

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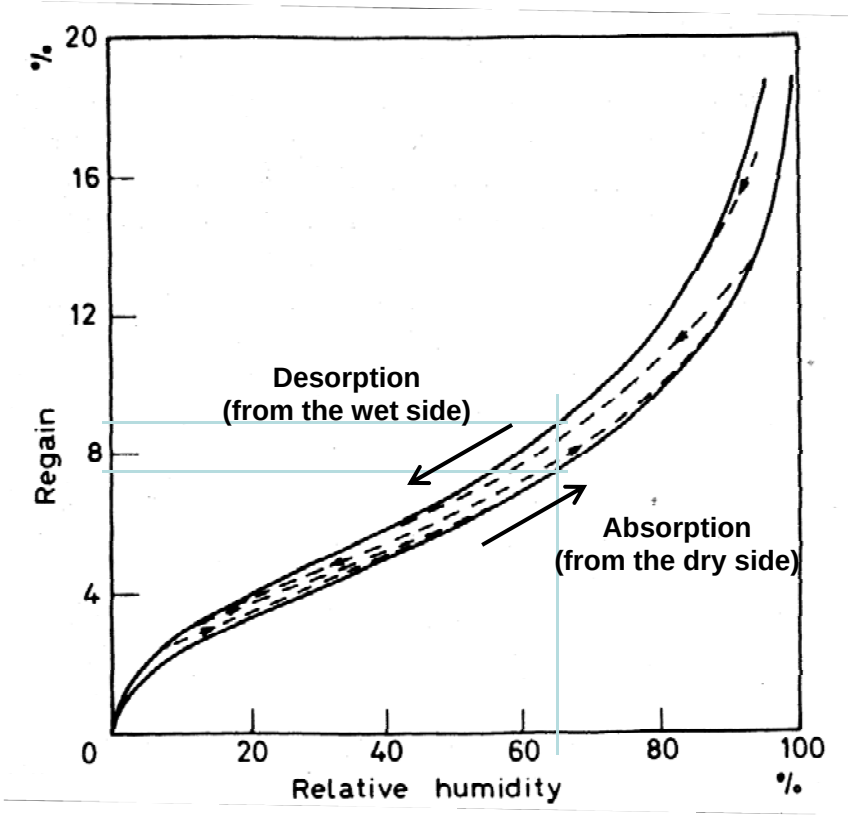
3.1- Reasons for working in standard conditions

- Equilibrium moisture content (dry basis): 6.75 - 8.25%
- Sample conditioning in approved atmospheric conditions
- Recommendation: start the conditioning from the dry

- Equilibre hygroscopique (taux de reprise) : 6.75 - 8.25%
- Conditions atmosphériques normalisées
- Recommandation: conditionner à partir de la masse sèche



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3.2- Standard requirements and tolerances

TEMPERATURE

Standard	Value	Tolerance	Resolution	Uncertainty
ISO 139:2005	20.0°C	± 2.0 °C	0.1 °C or better	± 0.5 °C or better
ISO 139:2005 alternative	23.0°C			
ASTM D 1776-08	70°F (21°C)	± 2°F (1°C)	N/A	N/A

RELATIVE HUMIDITY

Standard	Value	Tolerance	Resolution	Uncertainty
ISO 139:2005	65 %	± 4 %	0.1 % or better	± 2.0 % or better
ISO 139:2005 alternative	50 %			
ASTM D 1776-08	65 %	± 2 %	N/A	N/A

Resolution (of displaying device)
smallest difference between indications of displaying that can be meaningfully distinguished

Résolution (instrument)
La plus petite différence d´indication d´un dispositif afficheur qui peut être perçue de manière significative

Uncertainty of measurement
parameter, associated with the result of measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Incertitude (mesure)
Paramètre, associé au résultat d'un mesurage, qui caractérise la dispersion des valeurs qui pourraient raisonnablement être attribuées au mesurande

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3.2- Standard requirements and tolerances

TEMPERATURE

Standard	Value	Tolerance	Resolution	Uncertainty
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ISO 139 **21 ± 1°C**

ASTM D 1776 **65 ± 2 %**

RELATIVE HUMIDITY

Standard	Value	Tolerance	Resolution	Uncertainty
ISO 139:2005	65 %	± 4 %	0.1 % or better	± 2.0 % or better
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3.2- Standard requirements and tolerances

TEMPERATURE

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ISO 139
ASTM D 1776

21 ± 1°C
65 ± 2 %

Recommandation

± 0.5°C

RELATIVE HUMIDITY

Standard	Value	Tolerance	Resolution	Uncertainty
ISO 139:2005	65 %	± 4 %	0.1 % or better	± 2.0 % or better
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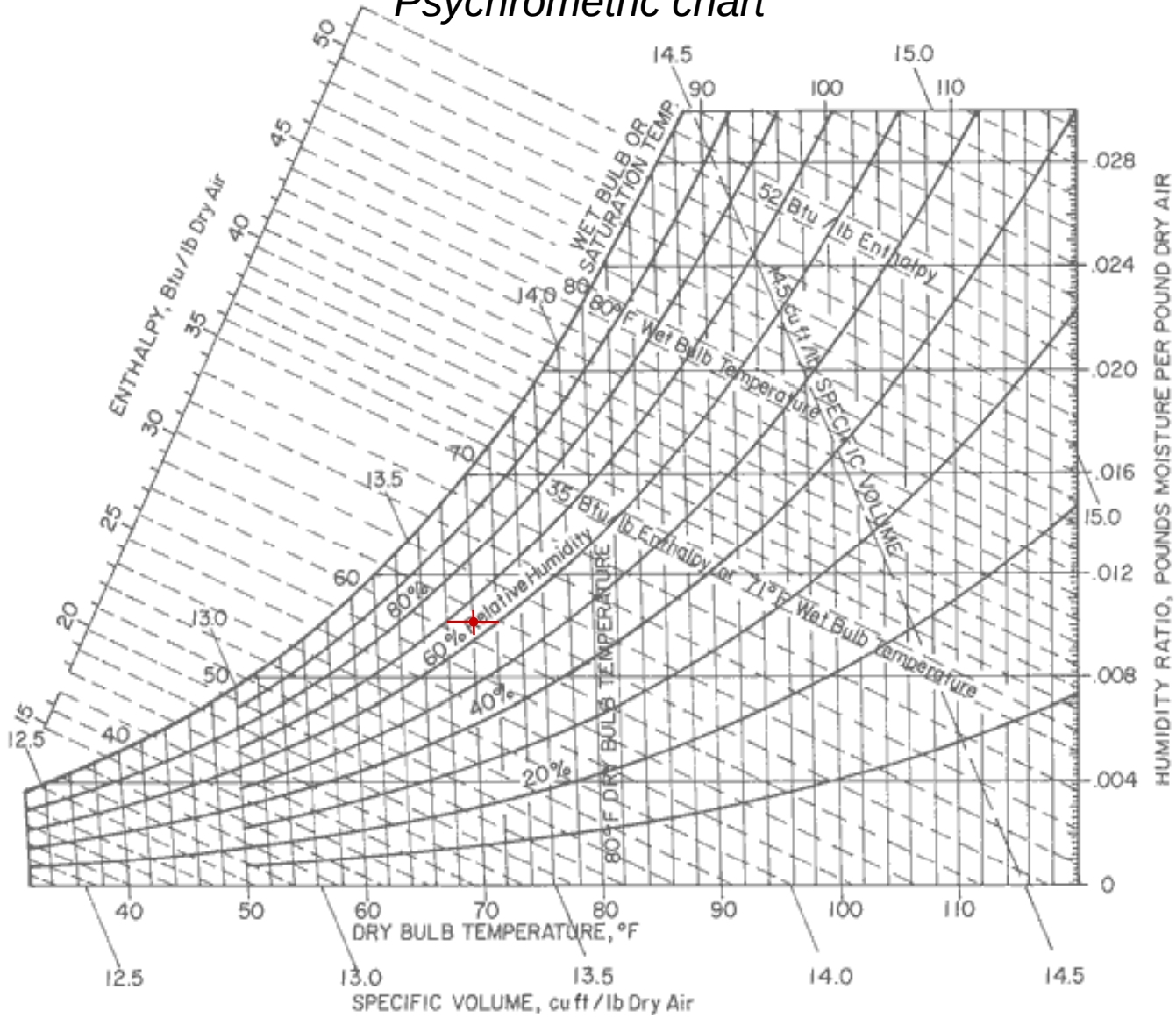
3.2- Standard requirements and tolerances

Psychrometric chart



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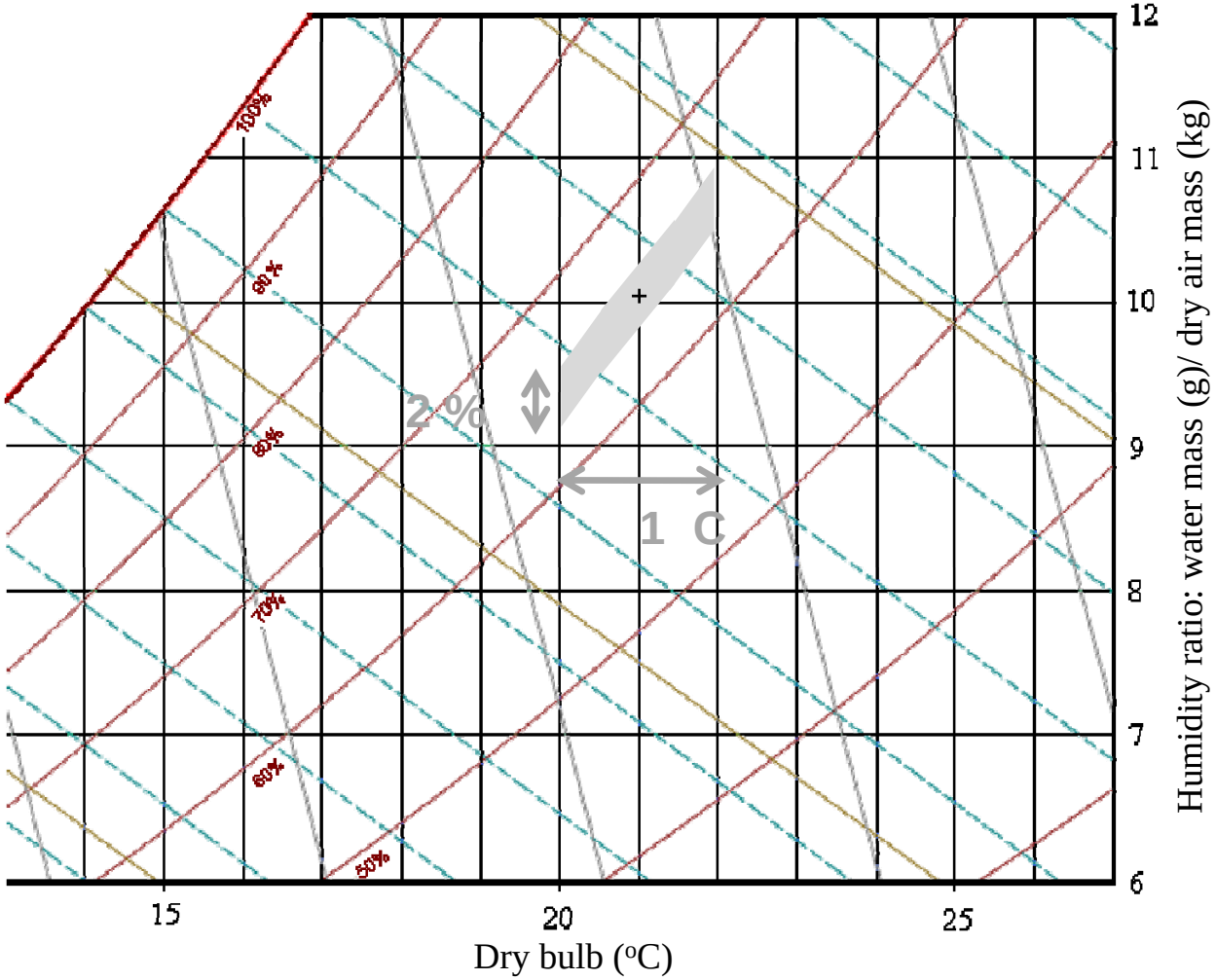
3.2- Standard requirements and tolerances

Psychrometric chart



\+ Point at 21°C and 65%

ASTM D1776 tolerance zone

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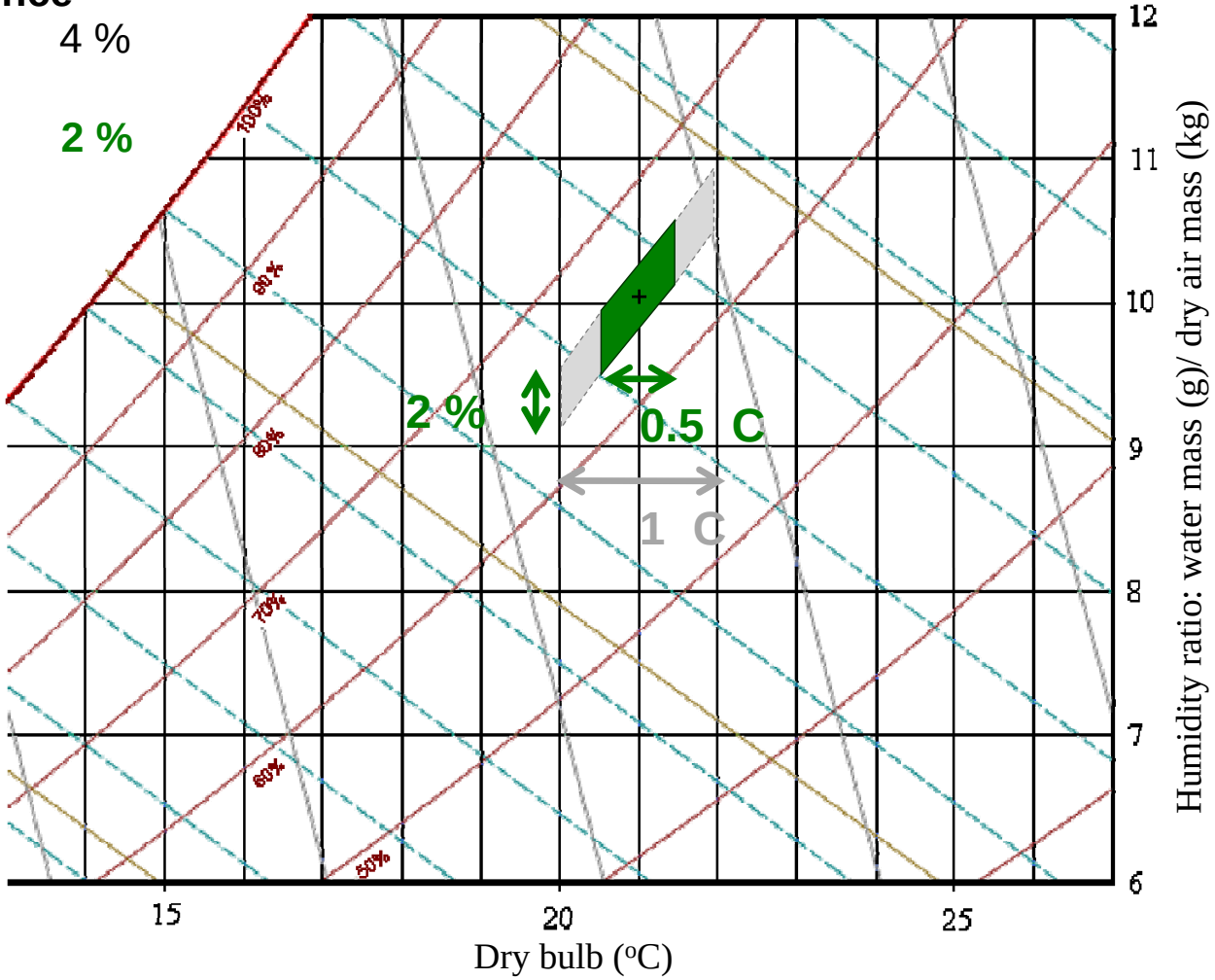
3.2- Standard requirements and tolerances

Equivalence

1 C ↔ 4 %

0.5 C ← 2 %

Psychrometric chart



\+ Point at 21°C and 65%

ASTM D1776 tolerance zone

Restricted tolerance zone

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3.3- Laboratory specifications

3.3.1- General specification

List of elements for calculating calorific power and heat balance, for properly localizing the return air ducts:

- Dimensions, area and volume of the room,
- Insulation, sunshine, temperature on each wall/glass, roof information,
- Laboratory equipment, lighting and other equipment, number of people in the room, number of entrances and airlocks
- …

Liste d'éléments nécessaires au calcul de la puissance calorifique et l'équilibre thermique, afin de placer correctement les bouches d'air :

- Dimensions, surface et volume de la salle,
- Isolation, ensoleillement, température sur chaque mur/fenêtre, information sur les toits,
- Equipement de laboratoire, éclairage et tout autre équipement, nombre de personnes dans la salle, nombre d'entrées et de sas
- …

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3.3- Laboratory specifications

3.3.2- Influence of insulation

- Energy saving
- Air conditions stabilising. Help abiding with the standardised atmospheres for conditioning and testing textiles
- Air conditioning system will be efficient only when specific requirements are fulfilled:
  - The laboratory has to be in the middle of the building, surrounded by corridors or office rooms so that external conditions could not affect the laboratory's. Failing this, the roof should be larger than the building to avoid its direct insulation, similarly to a penthouse.
  - If the laboratory is in a warehouse, it is necessary to help the air circulating between the roof and the ceiling of the laboratory rooms. Be careful of nuisance birds, rats…
  - Walls, ceilings and floors of laboratory must be thermally insulated.
  - Every door opening to the outside laboratory must be fitted out with an adapted airlock system, so that the two doors cannot open at the same time.
  - Air conditioning system must insure a small pressure in analysing rooms so that external conditions cannot interfere with the laboratory.
  - It is highly recommended to let the conditioning system running 24h per day and 7 days per week so that the room benefits of as stabilised conditions as possible. Thus, the conditioning and the complete testing of all the samples fulfil requirements of standard methods.
  - Room layout is of utmost importance. Indeed, height and structure of ceiling, as well as room volume must be known for calculating air outputs, number and position of air vents (return/renewal air).

- Economies d'énergie
- Stabilisation des conditions. Aide à demeurer dans l'atmosphère normale de conditionnement et d'essai des textiles
- Le système de conditionnement ne sera efficace que dans des conditions particulières :
  - Le laboratoire doit être au centre du bâtiment et entouré de bureaux, couloirs, etc. pour éviter l'influence des conditions extérieures : à défaut, le toit du bâtiment doit dépasser par rapport aux murs porteurs pour isoler les murs d'un ensoleillement direct et constituer une sorte d'auvent.
  - Si le laboratoire est englobé dans un hangar, il est nécessaire de favoriser une circulation d'air entre le toit et le plafond du laboratoire (attention aux oiseaux, rats…)
  - Les murs, le plafond et le sol du laboratoire doivent être isolés thermiquement du reste du bâtiment.
  - Chaque porte vers l'extérieur du laboratoire doit être équipée d'un sas d'entre d'une taille adaptée, de façon que les deux portes ne puissent pas s'ouvrir en même temps.
  - Le dispositif de conditionnement d'air doit assurer une surpression dans les salles d'analyse pour que les conditions extérieures ne perturbent pas le laboratoire.
  - Il est conseillé de laisser le conditionnement fonctionner jour et nuit, 7 jours/7 afin de stabiliser les conditions du laboratoire au maximum. Ainsi, le conditionnement et les essais sur tous échantillons peuvent être conformes aux normes.
  - L'organisation de la salle a une grande importance. En effet, la hauteur et la structure du plafond, comme le volume de la pièce doivent être connues pour le calcul des débits d'air, du nombre et de la disposition des bouches de ventilation, de reprise et de renouvellement d'air.

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3.4- Basic principles of AMS

3.4.1- Basics and drawing

- Objective: Maintain characteristics of ambient air within given tolerances

- Solution: Air Management System
  - Filtrated air distribution system
  - Control/regulation system: well-calibrated high sensitive T and RH sensors

    Measured air characteristics are compared to pre-set values; the regulation system gives commands to the operating system
  - Operating system: cooling, heating and steam humidifying (including water supply + water filtration system) systems (+ optional drying system)

    Each are provided with responsive valves to small changes demands within short delays

- Regulating system shall command **both** cooling/heating systems and humidifying/optional de-humidifying systems in the same time

- Objectif : Maintenir les caractéristiques de l'air ambiant dans les tolérances

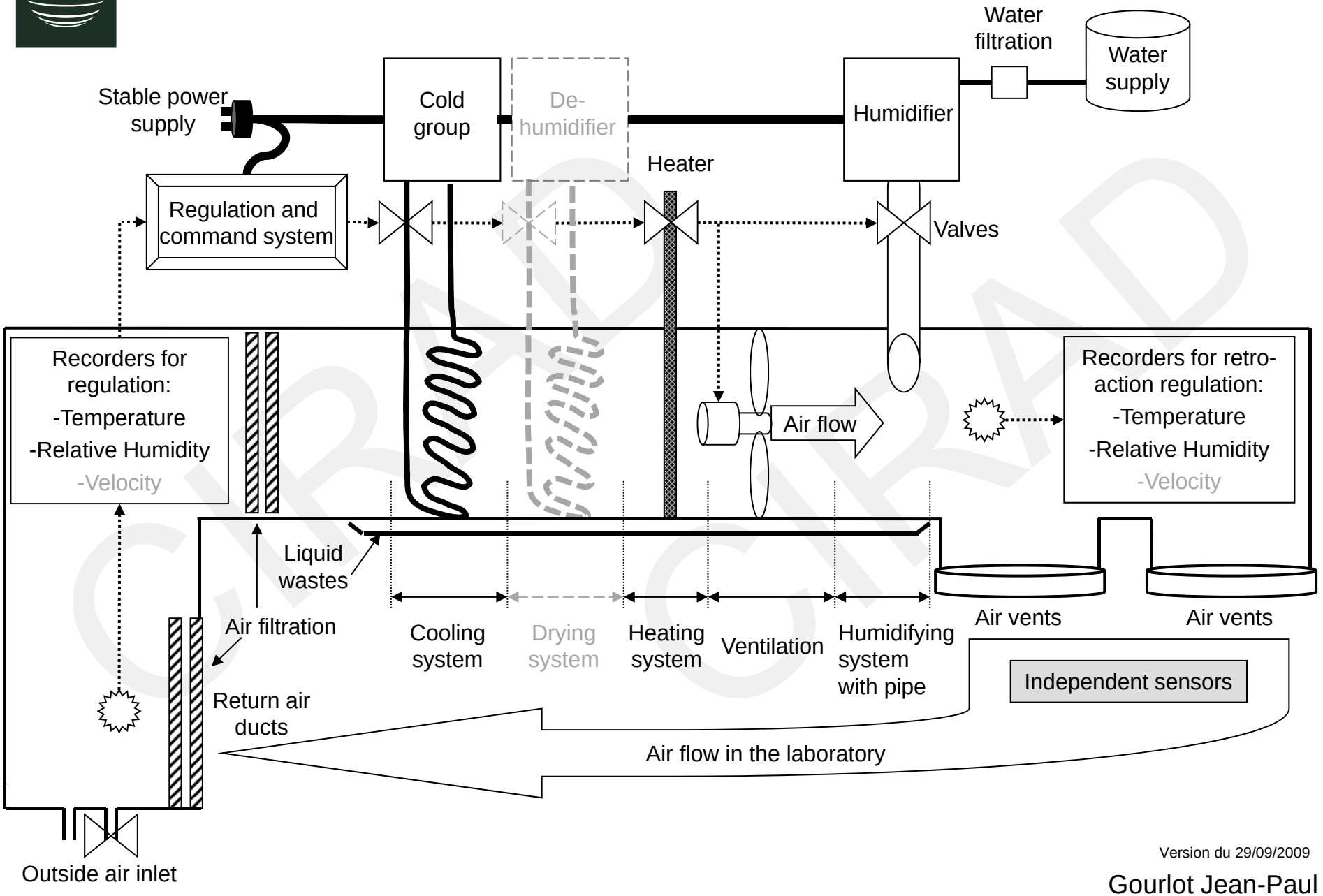
- Solution: Centrale de Traitement d'Air
  - Dispositif de distribution d'un air filtré
  - Dispositif de contrôle/régulation : sondes étalonnées et sensibles

    Les caractéristiques mesurées sont comparées à des valeurs prédéterminées ; le dispositif de régulation donne des instructions au :
  - Dispositif de fonctionnement: systèmes de refroidissement, de chauffage et d'humidification par la vapeur (dont approvisionnement d'eau filtrée) (+système de séchage facultatif)

    Chacun est équipé de valves réactives et sensibles aux faibles changements

- Le dispositif de régulation commande **à la fois** les systèmes de gestion de la température et de l'humidité

Schematic of proper air management system



Version du 29/09/2009

Gourlot Jean-Paul

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3.4- Basic principles of AMS

3.4.3- Independent vs interrelated regulation systems

- Difficulties of regulation

- If T+ then t+, h-
- If T- then t-, h+
- If H+ then h+, t+
- If H- then h-, t-

command observation

- Difficultés de la régulation

- Si T+ alors t+,h-
- Si T- alors t-,h+
- Si H+alors h+,t+
- Si H- alors h-,t-

command observation

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AMS vs independent control

Independent control

- Sensors
- Calibration
- Line
- Automaton
- Network
- Computer
- Software
- Database
- …

AMS

- **Sensors**
- **Calibration**
- **Line**
- **Comparator / Regulator**
- **Cooling system**
- **Heating system**
- **Humidifyer**
- **De-humidifyer**
- **Ventilation**
- **Air vents**
- **Air inlet**
- **Pipes**
- **…**

Result from a measurement of ambiant air characteristics in the rooms

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3.4- Basic principles of AMS

3.4.2- Summarized descriptive equipment for AMS

- List of required equipment for a proper AMS (assuming the system is correctly power supplied)

Control/regulation system	Operating system	Air flow
✓ Sensors for air temperature, relative humidity (and velocity) ✓ Calibration ✓ Comparator / Regulator ✓ Command	✓ Cooling system ✓ Heating system ✓ Steam humidifying system, water supply and filtration ✓ Drying system = dehumidifier (optional)	✓ Pipes (air ducts) ✓ Air inlets ✓ Air filtration ✓ Ventilation+air vents ✓ Aspiration+return air ducts

- Accuracy requirements for T and RH sensors:
  - regulation sensors, part of AMS equipment
  - Independant sensors, for equipment checking

Standard	Temperature		Relative Humidity	
	Resolution	Uncertainty	Resolution	Uncertainty
ISO 139:2005	0.1°C or better	± 0.5°C	0.1% or better	± 2.0%
ASTM D 1776-08	N/A	N/A	N/A	N/A

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3.4- Basic principles of AMS

3.4.2- Summarized descriptive equipment for AMS

- Equipment observed during expertise and their corresponding for a proper AMS

	Humidification	Air pipes	Cold group	Regulation	Adjustment
Observed material	Spray or fog humidification system	Air pipes without adjustable air vents	Cold group: single-stage vapour-compression refrigeration system (gas circulation)	Independent regulation systems (thermostat, hygrostat)	Binary system for valve opening command (0: close or 1: open)
Corresponding material for proper AMS	Steam humidification system	Air pipes with adjustable air vents (velocity control)	Cold group: chilled water as a refrigerant (water circulation)	Regulating system for both temperature and relative humidity (industrial PID regulators)	Fine adjustment for valve opening command (gradually opened from 0 to 100%)

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- Other recommandations

  - Equal distribution of the air: location of air vents and return air ducts must be adapted to each laboratory, depending on the areas of interest (to be defined),

  - Heating/cooling capacity: adding only power is not necessarily sufficient ; exchange surfaces on heating/cooling coils must also be adjusted.

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3.4- Basic principles of AMS

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3.4- Basic principles of AMS

3.4.3- Independent vs interrelated regulation systems

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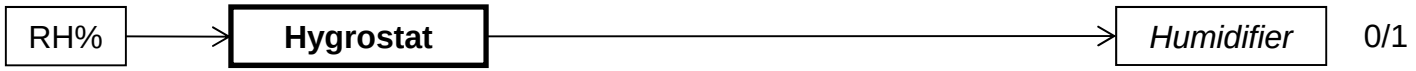
Wrong regulation system



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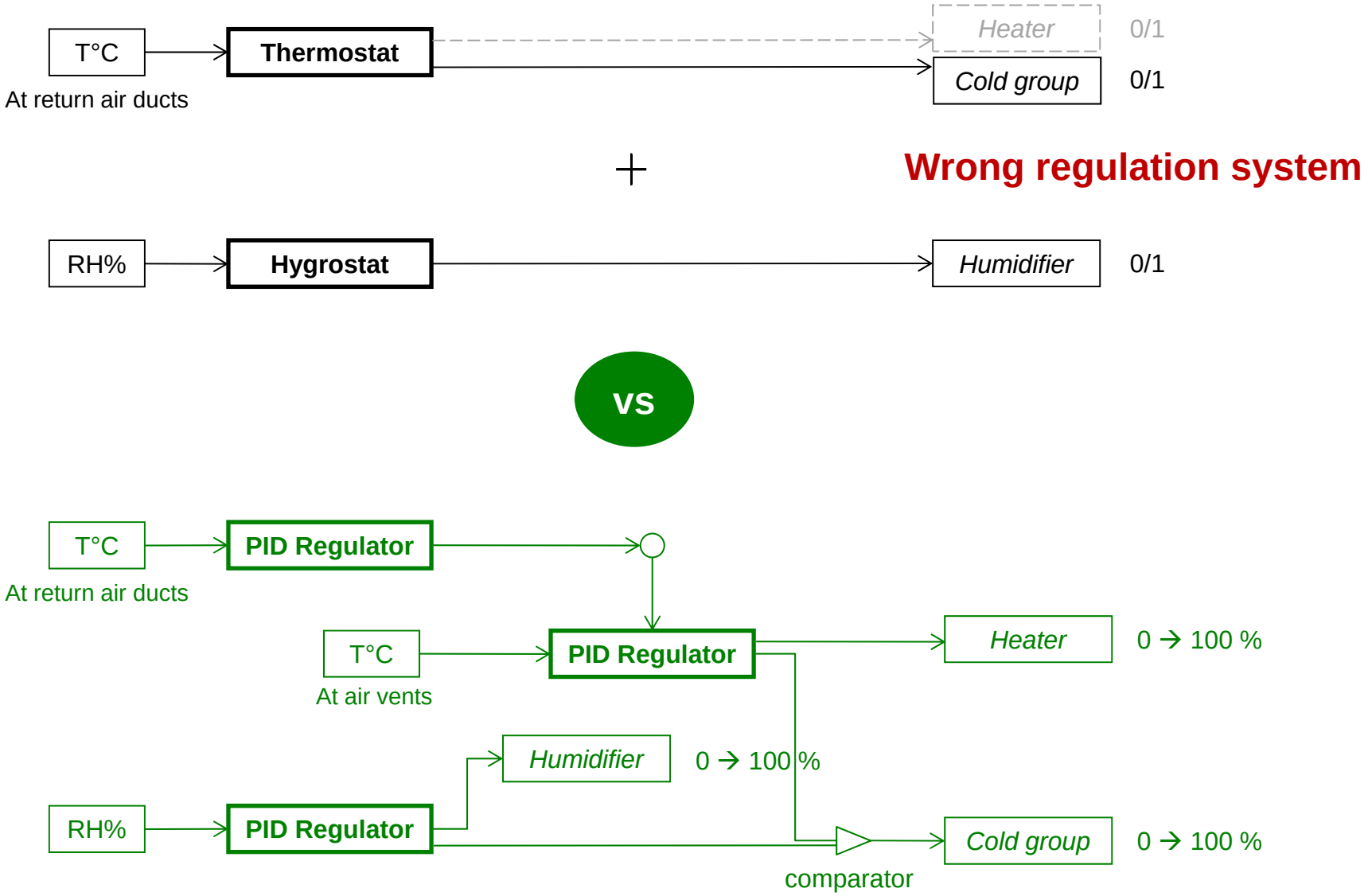
3.4- Basic principles of AMS

3.4.3- Independent vs interrelated regulation systems



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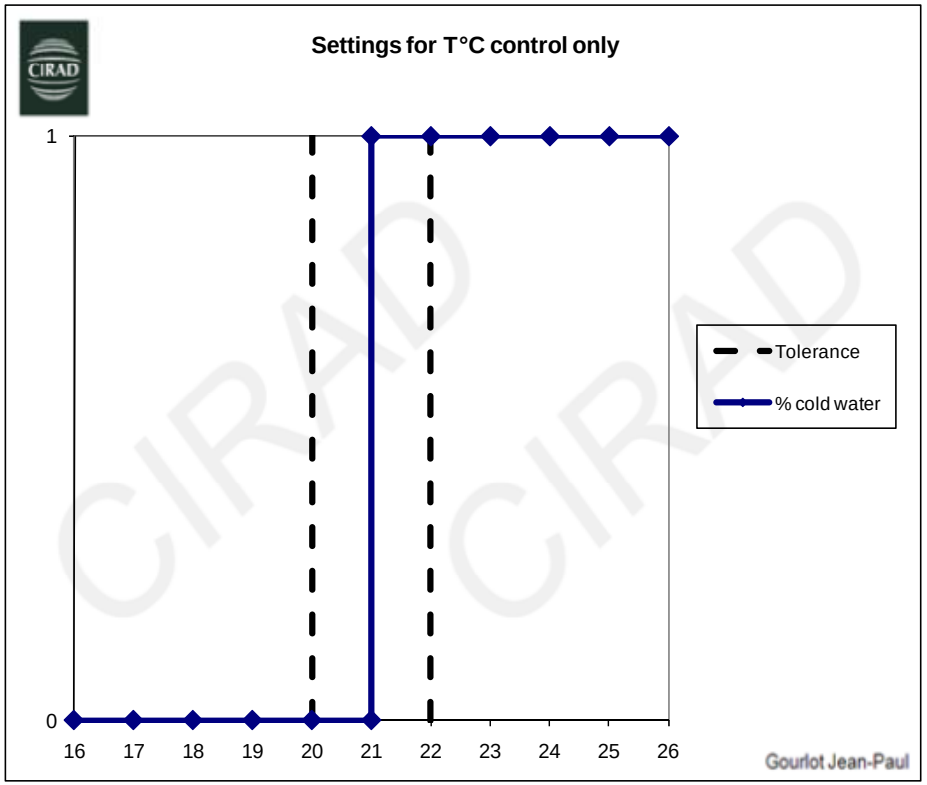
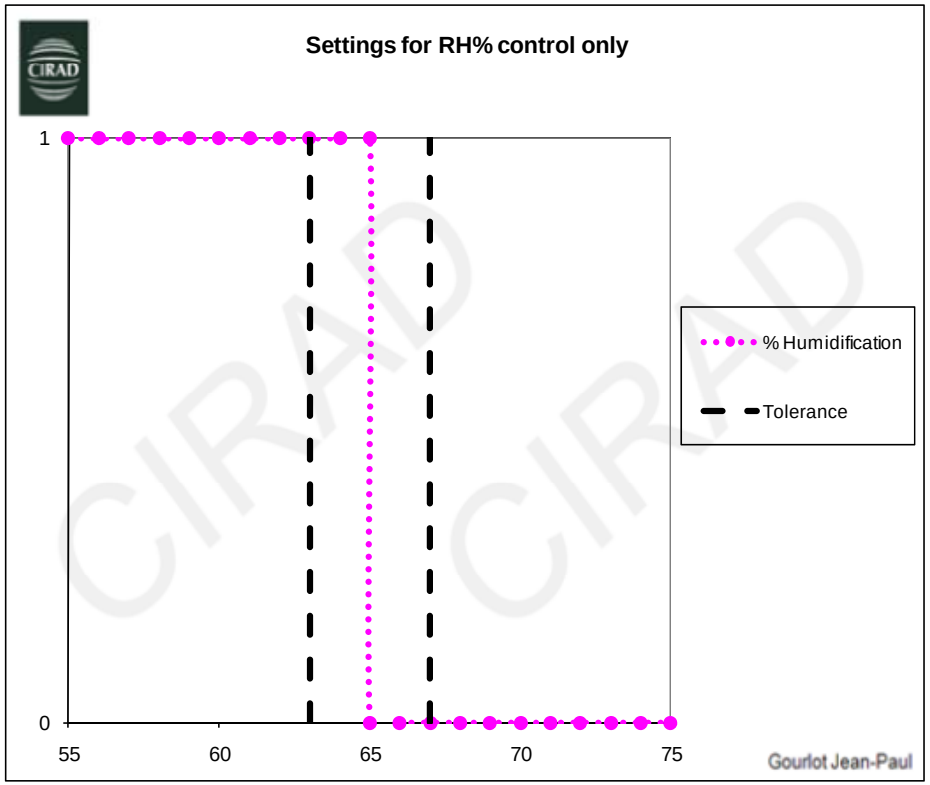
3.4- Basic principles of AMS

3.4.3- Independent vs interrelated regulation systems





Settings for independent cold goup and humidifier regulations

Wrong regulation system

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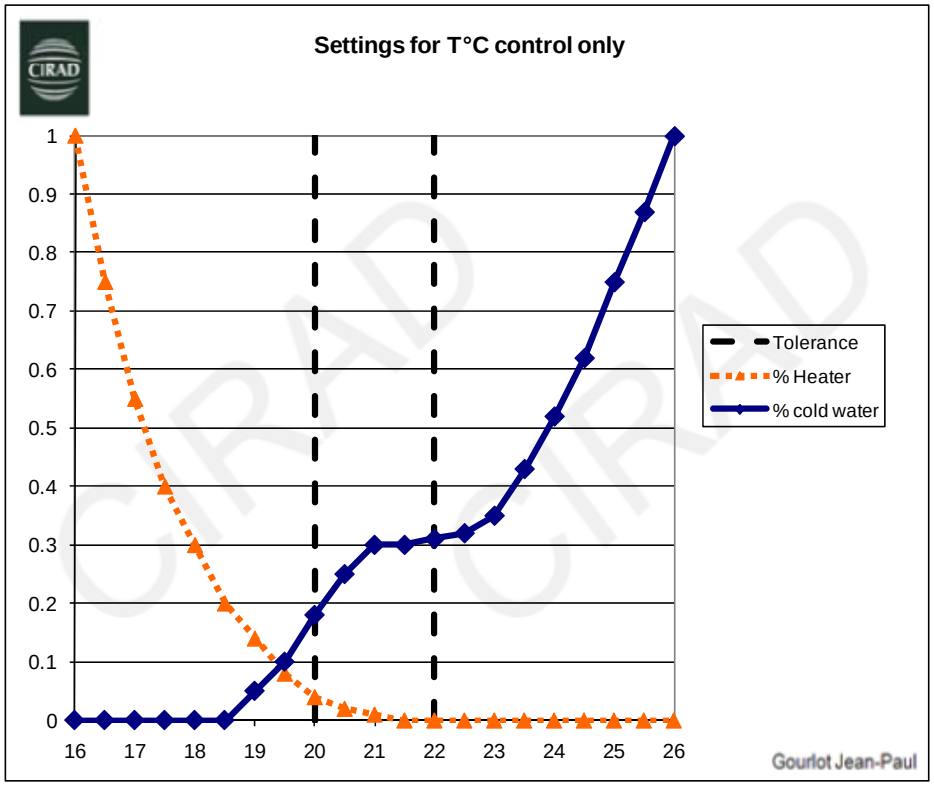
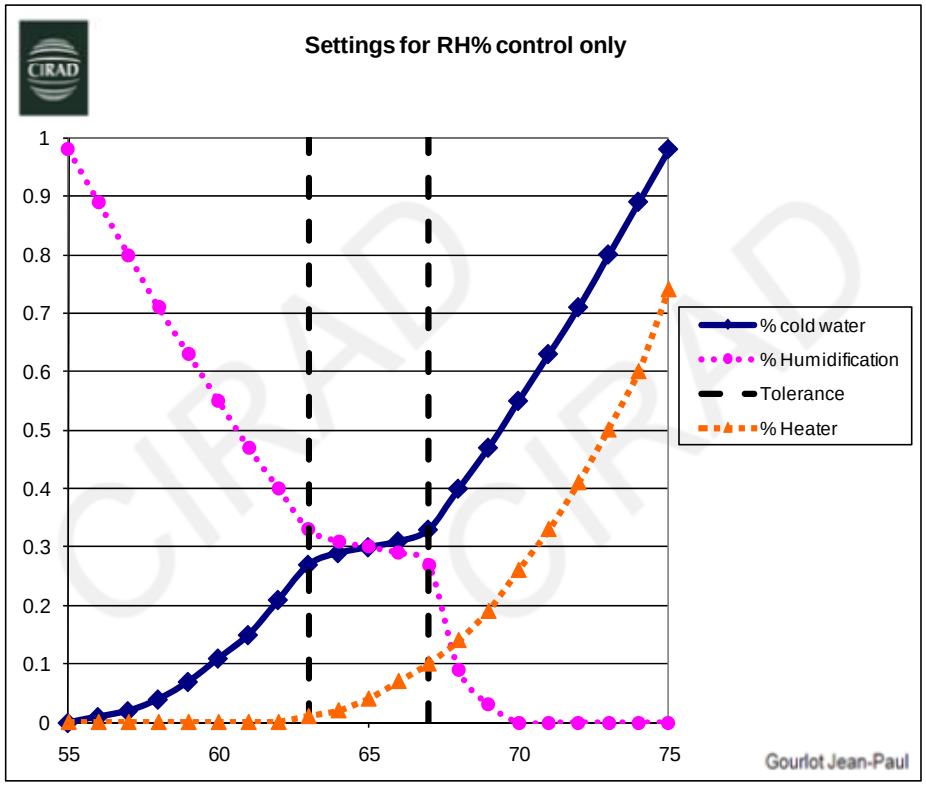
3.4- Basic principles of AMS

3.4.3- Independent vs interrelated regulation systems





Settings for interrelated chiller, heater and humidifier regulation
Correct regulation system

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AMS vs independent control

Independent control

- **Sensors**
- **Calibration**
- **Line**
- **Automaton**
- **Network**
- **Computer**
- **Software**
- **Database**
- **…**

AMS

- Sensors
- Calibration
- Line
- Comparator / Regulator
- Cooling system
- Heating system
- Humidifyer
- De-humidifyer
- Ventilation
- Air vents
- Air inlet
- Pipes
- …

Result from a measurement of ambiant air characteristics in the rooms

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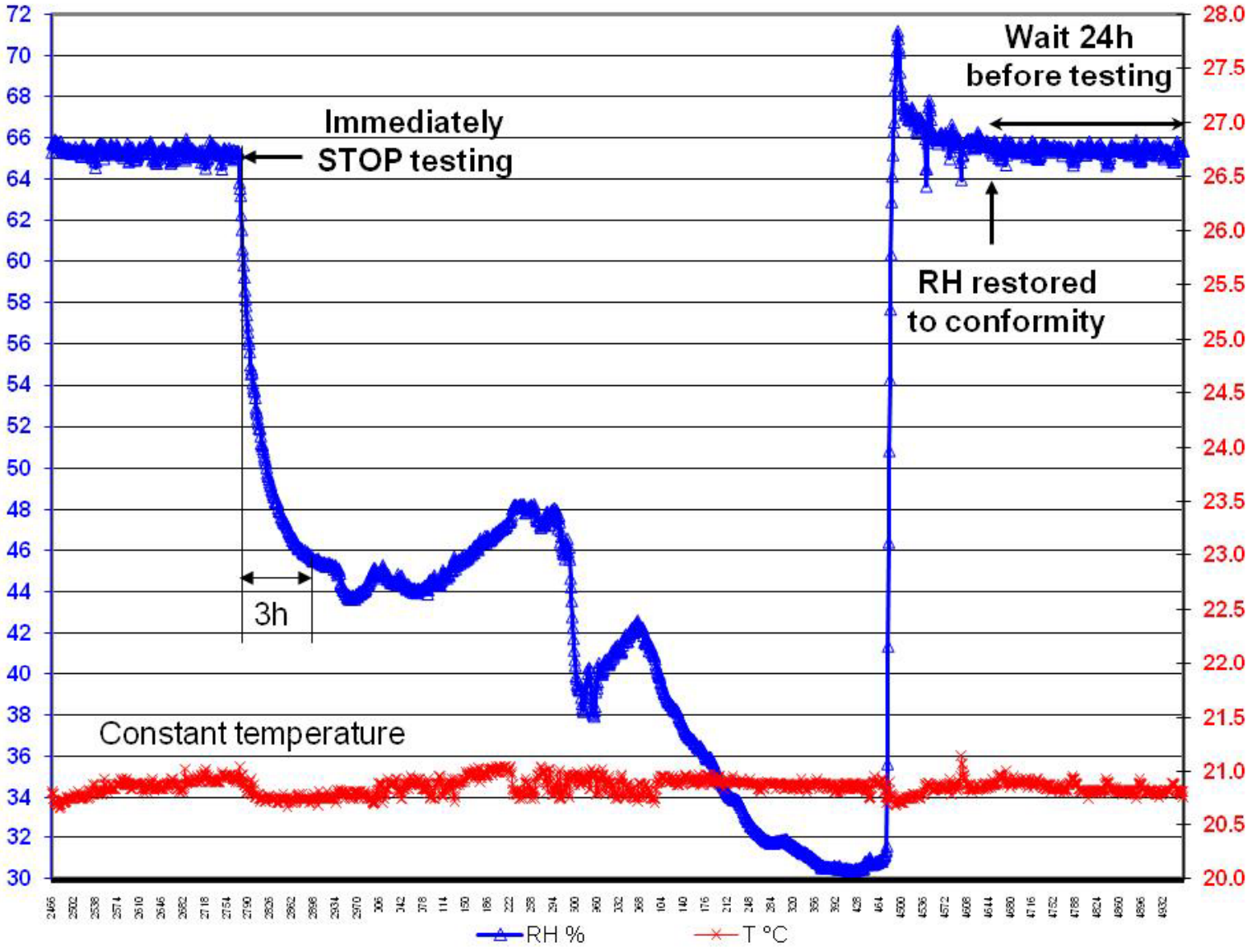
4.1- Example of short-time variation due to system failure



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4.2- Routine control procedure

4.2.1- General information

- Aim: prove that mean T and RH are stable within the tolerances over any continuous 1h period despite short-time and long-time heat variations
- Equipement: sensors independent from regulation system and as much sensitive
- Measurements:
  - at various locations: mini 1 sensor per 50 m^3 *(ISO 139:2005 Annex A)*
  - carried out periodically (e.g. 1 per min for digital or electronic equipment)
  - recorded round-the-clock and printed on a graph to check the ability of the conditioning device to respect permanently the tolerances
  - stored and easily released for investigation in case of controversial laboratory results. Keep all documents for traceability of sensor calibration and maintenance and of results.

- But : montrez que T et HR sont dans les tolérances pour n'importe quelle moyenne sur 1h malgré les fluctuations à court et long terme
- Equipement : sondes indépendantes de la régulation mais tout aussi sensibles
- Mesures :
  - à divers endroits : mini 1 sonde par 50 m^3 *(ISO 139:2005 Annex A)*
  - périodiques (ex : toutes les min pour les appareils électroniques)
  - enregistrées 24h/24 et imprimées sur un graphique pour vérifier de l'aptitude du dispositif à respecter les tolérances de manière permanente
  - stockées pour éventuellement les examiner en cas de contestation des résultats. Conserver tous les documents pour le traçabilité des étalonnages et de l'entretien préventif des capteurs ainsi que celle des résultats.

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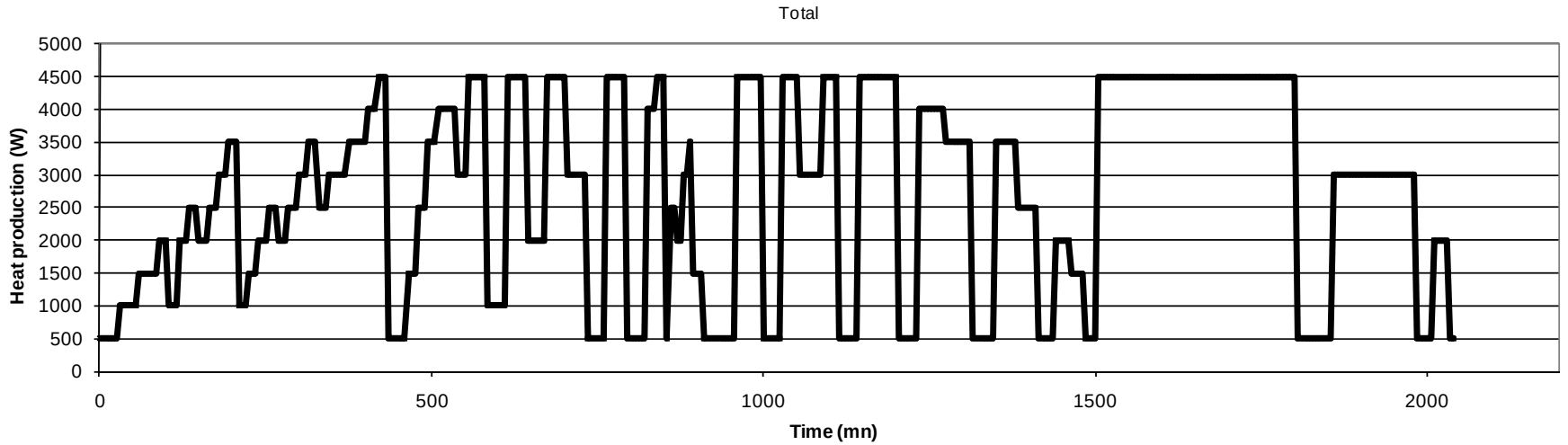
4.2- Routine control procedure

4.2.2- Checking the functioning

- When? Approving a new AMS installation / Periodic verification
- How? Heat changing experiment
- Observe the consequences of the changes on T and RH
- Observe how the system is reacting → Conclude how to settle better regulation rules and setting

- Quand ? Approbation de l'installation d'une CTA / Vérification périodique
- Comment ? Expérimenter l'évolution des sources de chaleur
- Observer les conséquences des variations sur T et HR
- Observer la réaction du système → Conclure sur les actions d'amélioration

Heat production in the room changing with heat sources activating
La puissance calorifique dans la salle évolue avec les variations des sources de chaleur



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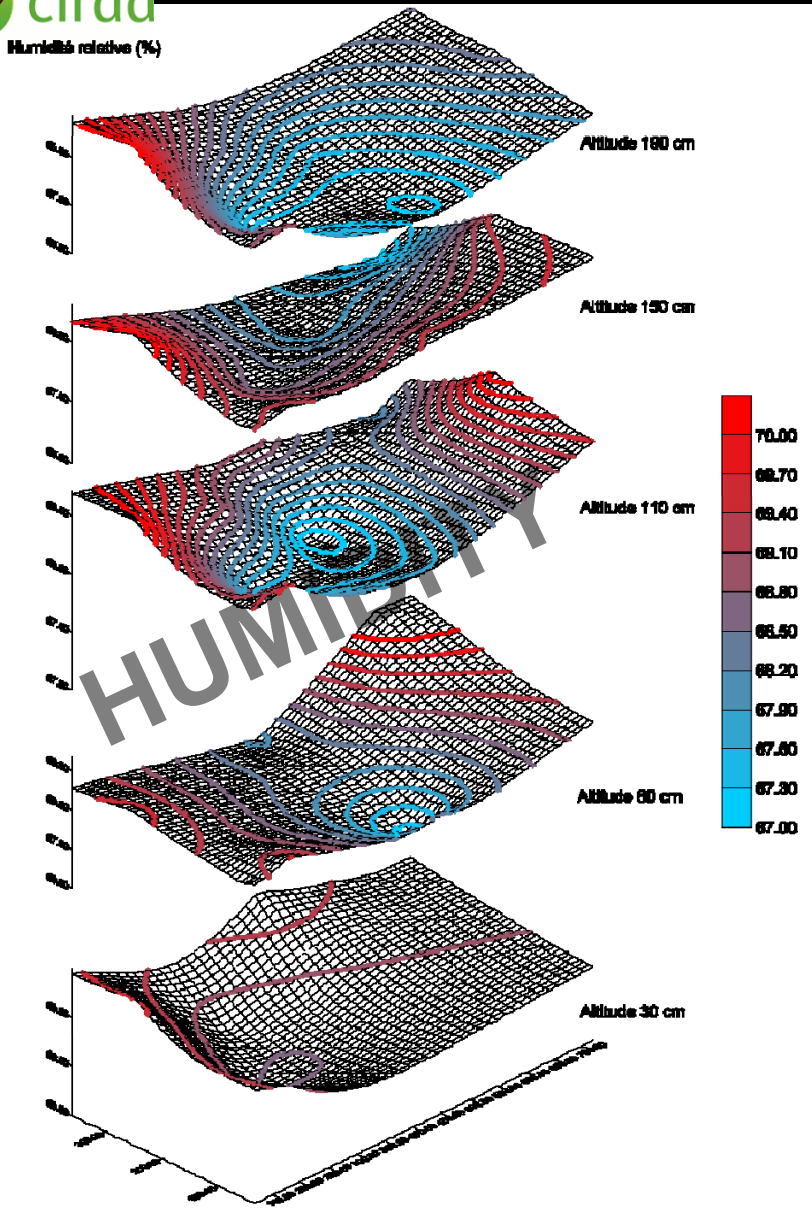
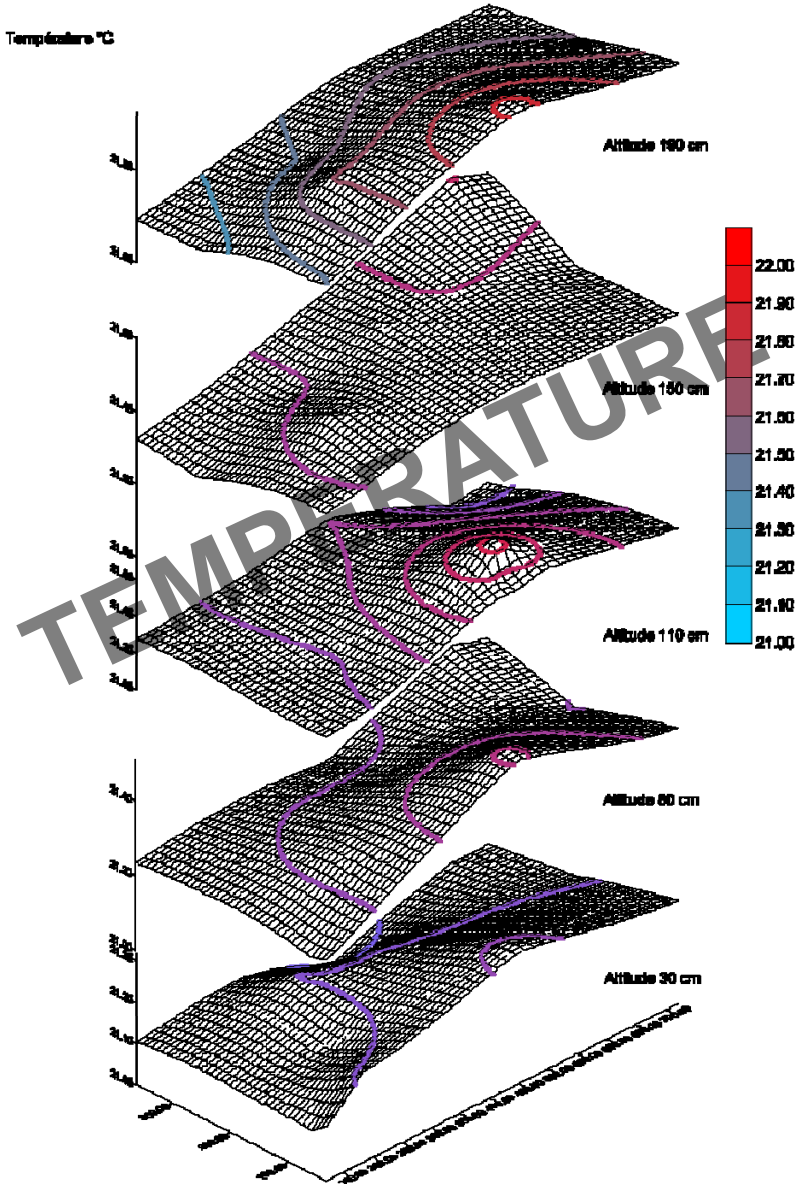
4.2- Routine control procedure

4.2.3- Example





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4.2- Routine control procedure

4.2.3- Example

Step 1: Studying the impact of external surroundings

Etape 1 : Etudier les influences extérieures

Step 2: Checking that sensors give reliable results

Etape 2 : Vérifier que les capteurs sont fiables

Step 3: Organising the volumetric measurements

Etape 3 : Organiser le système de mesures volumétrique

Step 4: Volumetric conditions measuring

Etape 4 : Mesurer la variabilité volumétrique des conditions

Step 5: Results gathering and interpreting

Etape 5 : Collecter et analyser les résultats

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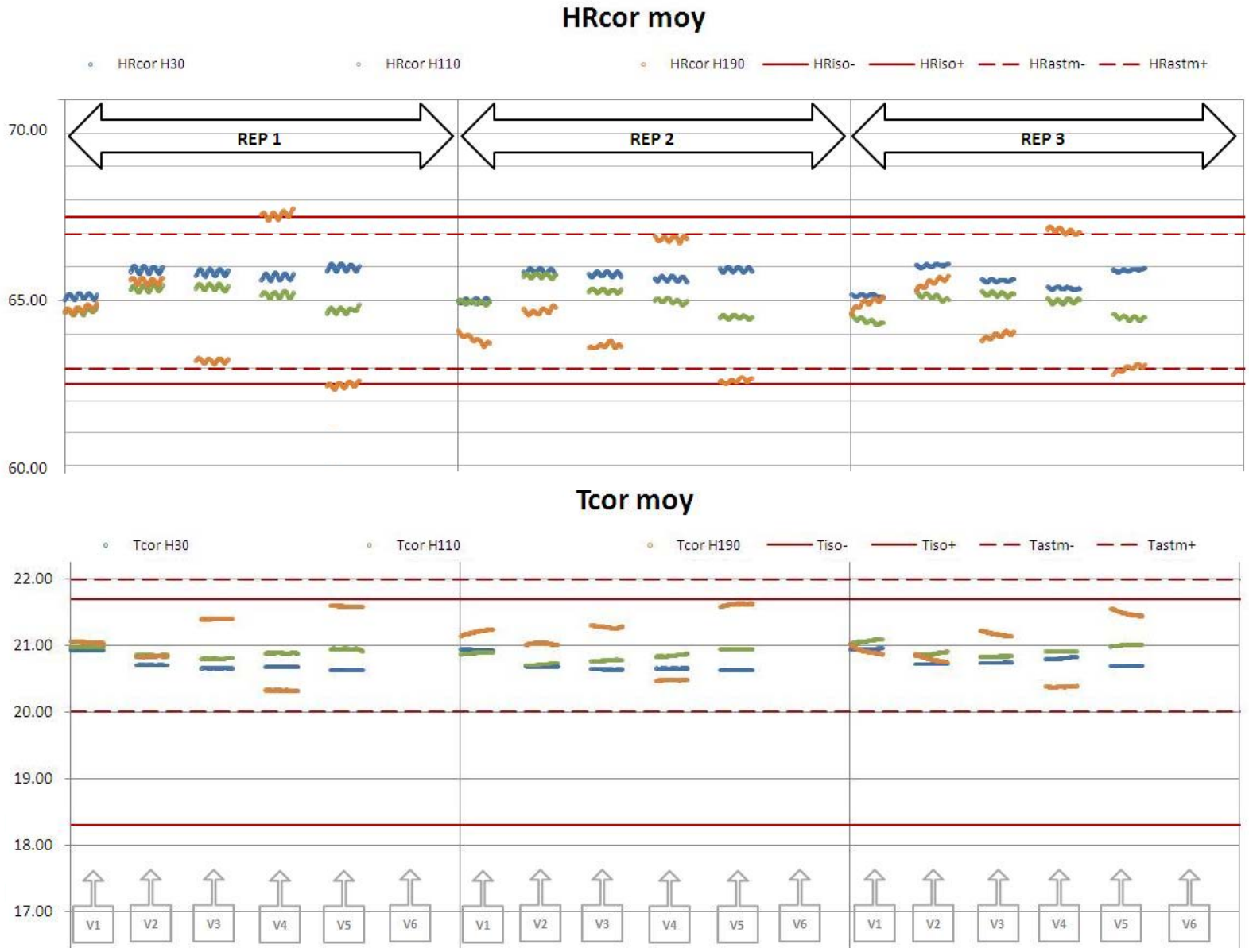
4.2- Routine control procedure

4.2.3- Example



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4.2- Routine control procedure

4.2.3- Example

- Duration (tests) — Duration (operator)

  Step 2 : 2 h (3 sensors simultaneously) x 3 rep
  = 6 h (on **1 day**) — 1h30 on 1 day

  Step 4 : 3 heights x 2 h (4 à 10 verticals simultaneously) x 3 rep
  = 18 h (on **3 days**) — 4h30 on 3 days

  Step 5 : requests + interpretation
  1 day (complete)

→ Total: one week of **5 days**

- Durée mesures — Temps opérateur

  Etape 2 : 2 h (3 sondes simultané) x 3 rép
  = 6 h (sur **1 jour**) — 1h30 sur 1 jour

  Etape 4 : 3 hauteurs x 2 h (4 à 10 verticales simultané) x 3 rép
  = 18 h (sur **3 jours**) — 4h30 sur 3 jours

  Etape 5 : requêtes + interprétation
  1 jour complet

→ Total sur une semaine de **5 jours**

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Plan of presentation

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5- Conclusion

- For complete satisfaction of AMS, 2 requirements are complementary:
  - power supply must be adapted
  - maintenance shall be performed regularly on AMS single elements

- You should now be able to:
  - respect completely the basic standards required for cotton testing
  - evaluate the ability of a manufacturer/ subcontractor to do his job
  - modify your climate system if necessary
  - prove your ability to maintain atmospheric condition within the worldwide agreed tolerances

- Call upon an engineering expert in air conditioning for laboratory if necessary

- Pour entière satisfaction de la CTA, 2 conditions complémentaires :
  - une alimentation en énergie adaptée
  - une maintenance régulière des éléments de la CTA

- Vous devriez maintenant pouvoir :
  - respecter complètement les normes relatives aux essais sur coton
  - évaluer la capacité d'un fabricant/sous-traitant à travailler correctement
  - modifier votre installation de conditionnement d’air si besoin
  - prouver votre capacité à maintenir les conditions atmosphériques dans les tolérances internationales

- Faire appel à un expert en ingénierie du conditionnement d’air pour laboratoire si besoin

All details in:

Tous les détails dans :

PAYET L., GOURLOT J-P., 2010, Rapport “D.1.3. Development of a list of requirements and basic principle drawings for a simple and efficient integrated climate control system”, Project CFC/ICAC/33, 23 p.

Thanks for your attention